PCT/GB99/03709

The Patent Office

INVESTOR IN PEOPLE

09/831665

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

GB99/3709

REC'D 16 DEC 1999
WIPO PCT

4

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

e-registration under the Companies Act does not constitute a new legal entity but merely ubjects the company to certain additional company law rules.

Signed

Dated 29.11.99

BLANK PAGE

Patents Form 1/77

Patents Act 1977
(Rule 16)

The Patent Office

THE PATENT OFFICE
A
11 NOV 1998
RECEIVED BY FAX

11NOV98 E403896-1 000354
F01/7700 0.00 - 9824689.5

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1.	Your reference	PJA/CH/C088284PGB
2.	Patent application number *(The Patent Office will fill in this part)*	**9824689.5** 11 NOV 1998
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	PROCESS TOMOGRAPHY FORESIGHT TECHNOLOGY LIMITED ST JAMES'S COURT BROWN STREET MANCHESTER M2 2JF
	Patents ADP number *(if you know it)*	7548688001
	If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM
4.	Title of the invention	MONITORING SYSTEM
5.	Name of your agent *(if you have one)*	Marks & Clerk
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Sussex House 83-85 Mosley Street Manchester M2 3LG
	Patents ADP number *(if you know it)*	18004
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country / Priority application number *(if you know it)* / Date of filing *(day/month/year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application / Date of filing *(day/month/year)*
8.	Is a statement of Inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if: a) any applicant named in part 3 is not an inventor, or b) there is an inventor who is not named as an applicant, or c) any named applicant is a corporate body. See note (d))*	YES

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	6
Claim(s)	3
Abstract	
Drawing(s)	2 /

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of Inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(Please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature.. Date 11/11/98
MARKS & CLERK

12. Name and daytime telephone number of person to contact in the United Kingdom — MR P.J. ALLMAN - 0161 236 2275

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 0645 500505.*
b) *Write your answers in capital letters using black ink or you may type them.*
c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*
d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*
e) *Once you have filled in the form you must remember to sign and date it.*
f) *For details of the fee and ways to pay please contact the Patent Office.*

MONITORING SYSTEM

The present invention relates to a system for monitoring conditions within a vessel a wall of which defines an enclosed space and a sensor array for mounting within such a vessel.

Process tomography systems have been designed which can obtain valuable information about process conditions within vessels. In many situations however it is undesirable or unacceptable to penetrate a process vessel with cables to enable communication with sensors located within that vessel. Typical situations in which such restrictions apply are stirred tank reactors, fluidised beds, separators, cyclones, hydraulic and pneumatic conveyors, crystallisers and the like. Particularly in the case of bioreactors where sterility is an essential requirement, it is highly undesirable to have cables penetrating the walls of such reactors.

Typical tomography systems require a symmetrically distributed set of transducers from which sample data produces a set of "projections" through the process. These are then "reconstructed" to form an estimate of the cross-section interrogated by the sensor array in terms of the parameters sensed by the transducers. A range of process information may then be estimated, for example volume fraction in a flowing mixture, solids concentration in stirred reactors, density distribution in a product and the like.

Typically transducers are arranged either singly or in pairs or in groups to measure a range of parameters. Examples are electrical capacitance measuring systems, electrical resistance measuring systems, electromagnetic inductance measuring systems, acoustic and ultrasound reflection and transmission measuring systems, X-ray transmission measuring systems, and nuclear magnetic resonance measuring systems. In some processes two or more types of transducers are used in order to gain sensitivity to a range of materials within the process. Such applications are typically described as multi-modal tomography applications.

When a set of distributed transducers is used it is desirable that each transducer comes into close contact with or proximity to the process at a particular geometric position. In a simple case each transducer may make such contact through a hole or opening formed at an appropriate location in a process vessel wall.

Although such an approach is simple and direct and can readily be used for experimental purposes and may be viable in some practical circumstances, there are also many situations in which such penetration of a vessel wall is undesirable.

A further problem which can be encountered when seeking to fit tomographic sensors within a process vessel is that of appropriately positioning sensors on the inside of a process vessel wall, particularly in situations where it is inappropriate to make connections to the sensors directly through that wall. There are also applications in which the process vessel includes mechanical structures such as stirrers which prevent the surface mounting of bulky sensor assemblies on the process vessel wall. This makes it very difficult in many circumstances for tomography sensors to be retro-fitted to existing process vessels.

It is an object of the present invention to obviate or mitigate some or all of the problems outlined above.

According to the present invention, there is provided a system for monitoring conditions within a vessel a wall of which defines an enclosed space, comprising a plurality of sensors which in use are distributed within the vessel, a first monitoring unit located within the vessel and connected to each of the sensors, and a second monitoring unit located outside the vessel, the first monitoring unit comprising means for converting sensor output signals into transmission signals which are transmissible through the vessel wall, and the second monitoring unit comprising means for detecting the transmission signals outside the vessel wall and deriving data representative of conditions within the vessel from the transmission signals.

The invention as defined above makes it possible to avoid penetrating a process vessel wall with any cables even in the event that for example a tomographic sensing system incorporates a large number of sensors.

Preferably, means are provided for transmitting a power signal from outside the vessel to the first monitoring unit, the first monitoring unit comprising a detector arranged to detect the power signal and a power supply energised by the detected power signal.

The first monitoring unit may comprise an antenna and an associated detector circuit tuned to a predetermined frequency, and the power signal may be transmitted at the predetermined frequency.

The vessel may incorporate a window, and the first monitoring unit may be arranged to transmit optical transmission signals through the window to the second monitoring unit. The first monitoring unit may comprise a laser to generate the optical transmission signals. The optical signals may be infra-red signals.

The transmission signals may be radio telemetry signals to which at least a part of the vessel wall is transparent.

The plurality of sensors may be carried by a sheet which is secured on the inside face of the vessel wall, the sensors being connected to the first monitoring unit via conductive tracks formed on the sheet.

The present invention also provides a sensor array for mounting within a vessel to enable conditions within the vessel to be monitored, comprising a sheet which may be secured to an inner surface of the wall of the vessel, the sheet carrying the array of sensors and conductive tracks connecting the sensors to at least one output through which signals may be transmitted which are representative of conditions to which the sensors are exposed.

The invention as defined in the preceding paragraph makes it possible to readily position sensors suitable for connection to for example a tomographic imaging system inside a process vessel without requiring significant clearance above the original process vessel wall surface, the relative positioning of different components of the sensor array being determined by the position of the components on the sheet.

The conductive tracks may be covered with an electrically insulating layer, and the sensors may also be covered with the electrically insulating layer.

The sheet may be flexible.

The sheet may comprise a series of sections which are interconnected such that at least some of the conductive tracks extend across the interconnections between the sections.

Referring to the accompanying drawings, an embodiment of the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a vertical section through a process vessel incorporating a tomographic sensing system in accordance with the present invention;

Figure 2 is a plan view of a flexible sheet supporting a single electrode which is incorporated in the process vessel of Figure 1;

Figure 3 is a plan view of part of a further sheet carrying two electrodes also incorporated in the process vessel of Figure 1; and

Figure 4 is a section on the line 4-4 of Figure 2.

Referring to Figure 1, the illustrated process vessel has a wall 1 which completely encloses a space 2 within which for example a fermentation process is to be carried out. The vessel 1 has a steel wall in which a glass window 3 is provided, such windows being commonplace in process vessels to enable a visual inspection of the vessel contents. A first monitoring unit 4 is secured to the inside surface of the window 4 and a second monitoring unit 5 is secured to the outside surface of the window 4.

The first monitoring unit 4 is connected by a multi-way cable 6 to an electrode assembly which extends around the inner surface of the process vessel. The electrode assembly is made up of a series of units three of which are shown in Figure 1, that is units 7, 8 and 9. Each of the units is in the form of a flexible sheet adhered to the inner surface of the process vessel, the units being interconnected end to end. Figure 2 is a plan view of a sheet which can be used as the unit 7 or 8 in Figure 1. Figure 3 is a plan view of a sheet which can form the unit 9 of Figure 1. Figure 4 is a section through the sheet of Figure 2 in the direction of lines 4-4 in Figure 2.

Referring to Figures 2 and 4, the illustrated unit comprises a flexible electrically insulating substrate 10 upon which a copper electrode 11 and a series of conductive tracks 12 have been printed. An insulating layer 13 covers the conductive tracks 12 but does not cover the surface of the electrode 11 which is on the far side of the substrate 10 from the vessel wall 1. Accordingly resistance measurements may be made between any one electrode and one or more of the other electrodes in the array which are spaced around the process vessel. Each of the electrodes 11 is connected by a respective pair of tracks 12 to a terminal in a terminal array 14 provided on the electrode unit 9 (Figure 3). Each of those terminals is in turn connected by the cable 6 to the first monitoring unit 4.

Data derived from the electrodes 11 is optically coupled through the window 3 to the second monitoring device 5. The signals coupled through the window 3 may

simply directly represent outputs derived from the electrodes 11, or those outputs may be processed in the first monitoring unit 4 before transmission to the second monitoring unit 5. Thus large amounts of data may be picked up by the electrode array and transmitted to the exterior of the process vessel without it being necessary for the process vessel wall to be penetrated in any way. In the event that the process vessel has to be sterilised between processing operations the electrode array is robust and can be readily cleaned.

Given that the electrodes 11 are mounted on an insulating substrate 10 which extends to a substantial distance away from the edges of the electrodes 11, electrical fields which can be generated within a process fluid within the process vessel are not shorted out to the process vessel wall at positions close to the electrodes. Thus electrical fields emanating from the electrodes 11 can extend a substantial distance into the body of the fluid contained by the vessel. Useful data can be obtained using conventional resistance tomography techniques.

Electrode arrays may be made up from a number of the individual units such as those illustrated in Figures 2 and 3 so as to make it possible to fit electrode arrays in process vessels of different sizes using essentially standard components. Individual electrode array units may be connected end to end using the end-connectors shown in Figures 2 and 3. The electrode arrays are thin and therefore can be readily shaped so as to be adhered closely to the walls of a process vessel, enabling their use in applications where the electrode arrays cannot project substantially from the internal wall of the vessel, for example when retro-fitting electrode arrays to vessels in which stirrers are provided which sweep across the inner surface of the vessel walls. It is a relatively easy matter to produce electrode assemblies with an installed thickness of only a few millimetres.

In the illustrated case, the electrodes 11 are not insulated from the process fluids. This is appropriate in the case of an electrode array used for resistance measurements. Other tomographic configurations are however possible, for example systems based on capacitance measurement. In the case of a system used for capacitance measurements, the electrodes 11 would be covered by the insulating layer 13.

Although in the illustrated case communication between the interior and exterior of the vessel is achieved through a window 3, it will be appreciated that the cable 6 could be fed through a suitably sealed opening in the process vessel wall, thereby enabling a direct connection to be made between the electrodes and the external monitoring unit 5.

In the case illustrated in Figure 1, it is necessary to energise the first monitoring unit 4. This could be achieved using a suitable battery-energised power pack but this would require periodic replacement of the battery. In an alternative arrangement the first monitoring unit 4 may be energised using a remote link relying upon for example inducing electrical energy by transmitting a power signal from the second monitoring unit to the first, the first monitoring unit being provided with an antenna and a detector tuned to detect the power signal, and the detector providing an output to an appropriate power supply.

In the case illustrated in Figure 1, data is transferred between the first and second monitoring units using an optical link, for example relying upon a laser or other simple optical transmission and reception systems. Other non-contact telemetry options are available however, for example infra-red systems and radio telemetry links.

CLAIMS

1. A system for monitoring conditions within a vessel a wall of which defines an enclosed space, comprising a plurality of sensors which in use are distributed within the vessel, a first monitoring unit located within the vessel and connected to each of the sensors, and a second monitoring unit located outside the vessel, the first monitoring unit comprising means for converting sensor output signals into transmission signals which are transmissible through the vessel wall, and the second monitoring unit comprising means for detecting the transmission signals outside the vessel walls and deriving data representative of conditions within the vessel from the transmission signals.

2. A system according to claim 1, wherein means are provided for transmitting a power signal from outside the vessel to the first monitoring unit, the first monitoring unit comprising a detector arranged to detect the power signal and a power supply energised by the detected power signal.

3. A system according to claim 2, wherein the first monitoring unit comprises an antenna and an associated detector circuit tuned to a predetermined frequency, and a power signal is transmitted at the predetermined frequency.

4. A system according to any preceding claim, wherein the vessel incorporates a window, and the first monitoring unit is arranged to transmit optical transmission signals through the window to the second monitoring unit.

5. A system according to claim 4, wherein the first monitoring unit comprises a laser to generate the optical transmission signals.

6. A system according to claim 4 or 5, wherein the optical transmission signals are infra-red signals.

7. A system according to claim 1, 2 or 3, wherein the transmission signals are radio telemetry signals to which at least a part of the vessel wall is transparent.

8. A system according to any preceding claim, wherein the plurality of sensors are carried by a sheet which is secured on the inside face of the vessel wall, the sensors being connected to the first monitoring unit by conductive tracks formed on the sheet.

9. A sensor array for mounting within a vessel to enable conditions within the vessel to be monitored, comprising a sheet which may be secured to an inner surface of the wall of the vessel, the sheet carrying the array of sensors and conductive tracks connecting the sensors to at least one output through which signals may be transmitted which are representative of conditions to which the sensors are exposed.

10. A sensor array according to claim 9, wherein the conductive tracks are covered with an electrically insulating layer.

11. A sensor array according to claim 10, wherein the sensors are covered with the electrically insulating layer.

12. A sensor array according to claim 9, 10 or 11, wherein the sheet is flexible.

13. A sensor array according to claim 9, 10, 11 or 12, wherein the sheet comprises a series of sections which are interconnected such that at least some of the conductive tracks extend across the interconnections between the sections.

14. A system for monitoring conditions within a vessel a wall of which defines an enclosed space substantially as hereinbefore described with reference to the accompanying drawings.

15. A sensor array for mounting within a vessel to enable conditions within the vessel to be monitored substantially as hereinbefore described with reference to the accompanying drawings.

THIS PAGE BLANK (USPTO)

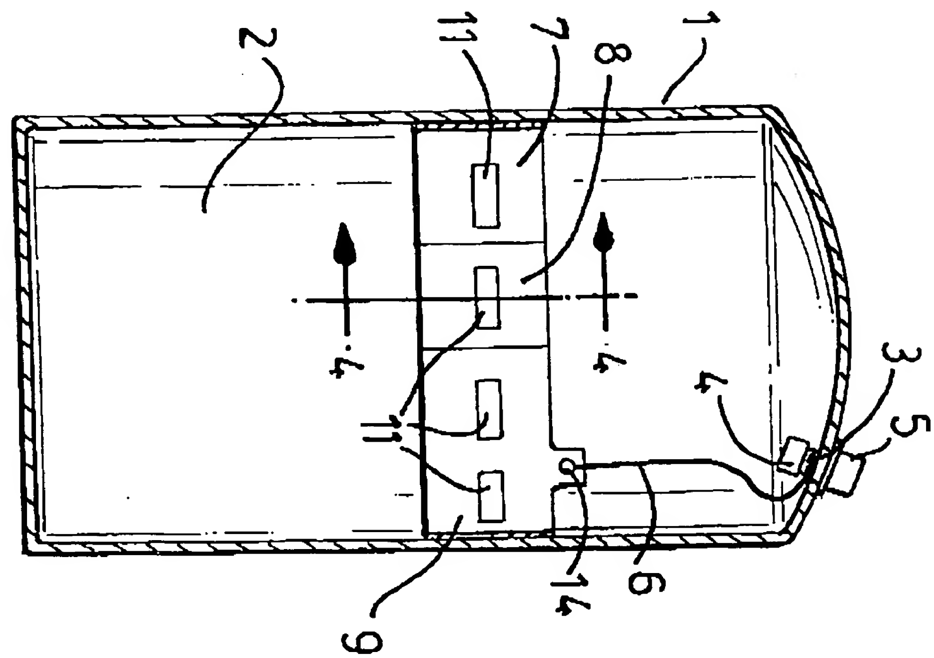


FIG. 1

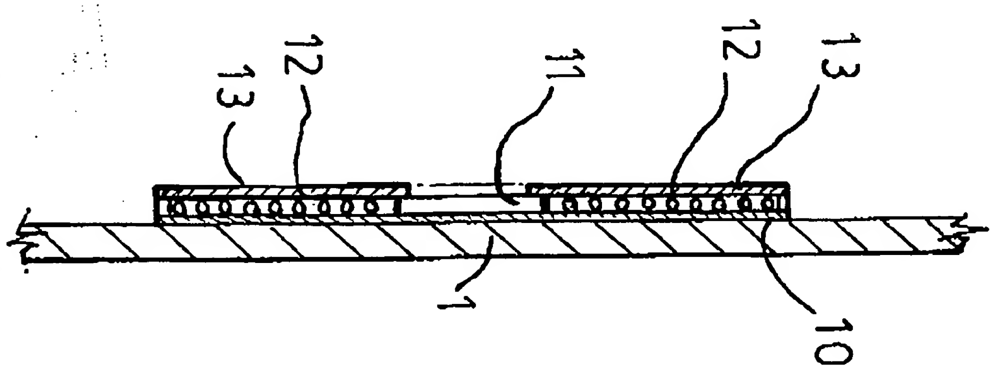


FIG. 4

FIG. 3

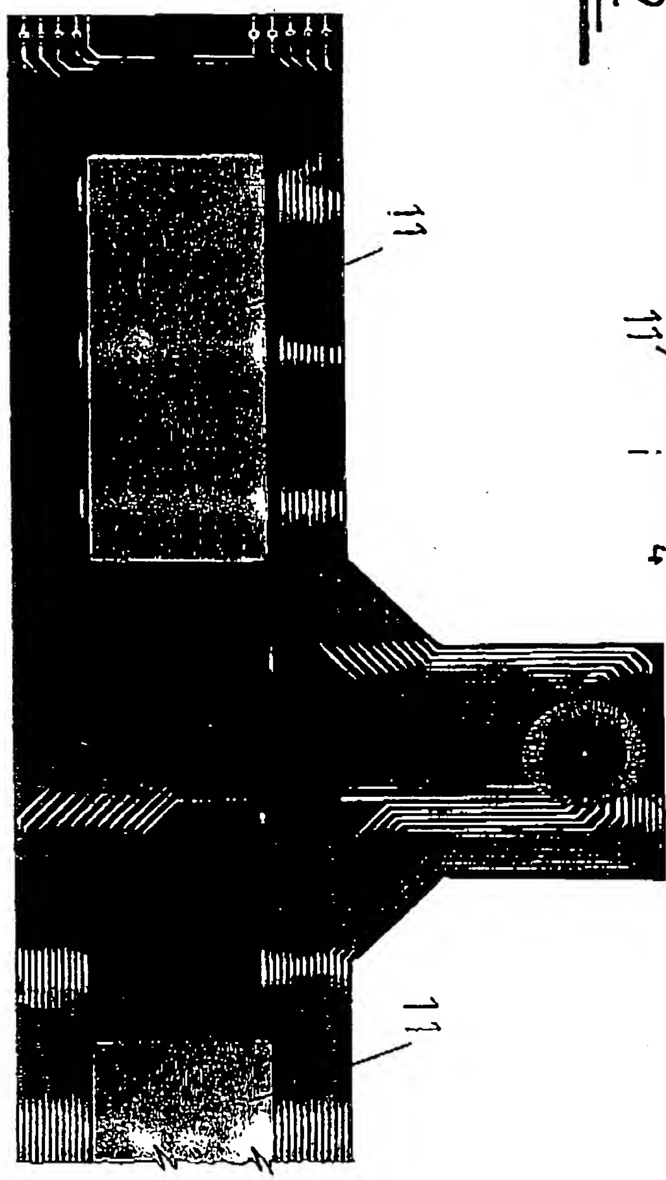
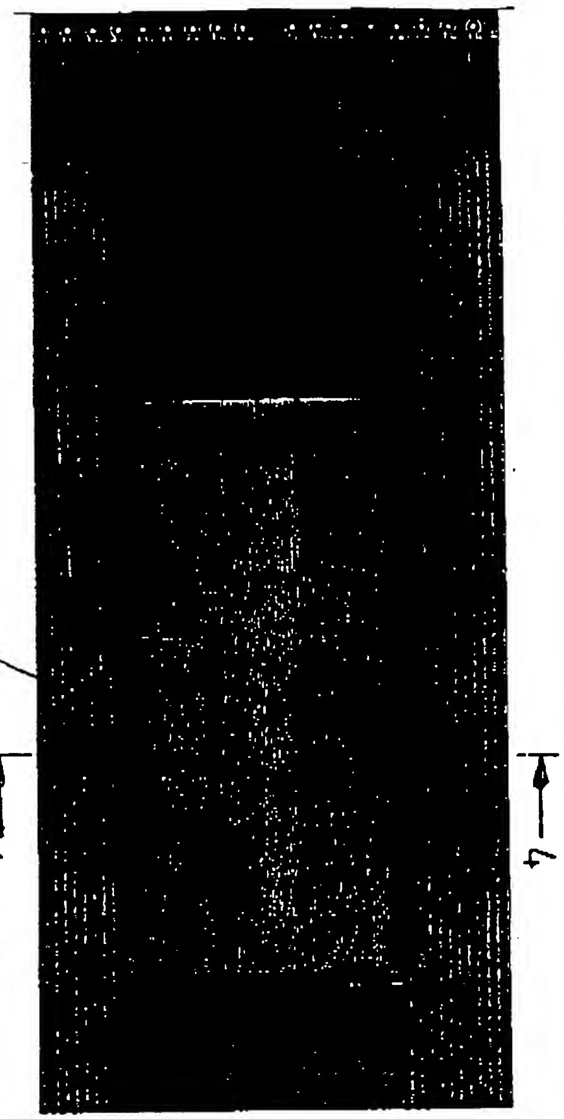


FIG. 2



PCT/GB99/03799
Marks & Clerk
19.11.99